POSSIBILITIES OF THE USE OF WORKING SELF-CONTAINED BREATHING APPARATUSES FILTRATING CARBON MONOXIDE IN THE PRACTICE OF MINE RESCUE SERVICES

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Abstract

In the current practice of the Mining Rescue Service of the Czech Republic, since 2005, the insulated overpressure regenerative breathing apparatuses with a closed circuit and supply of medicinal oxygen are used as the backbone working breathing apparatuses. At the end of the year 2010, the compressed-air breathing apparatuses were introduced into the practice of the Mining Rescue Service of the Czech Republic, which, in precisely defined types of mine rescue service interventions and under precisely defined conditions, can replace the aforementioned backbone working insulated overpressure regenerative breathing apparatuses. Recently, mining rescue services in deep coal mines have been more and more often conducted under conditions of an irrespirable mine atmosphere containing high concentrations of carbon monoxide, but at the same time containing sufficient oxygen for the breathing physiology of mine rescuer (for example, interventions dealing with the disposal of machinery under conditions of occurrence of endogenous mining fire of coal). This fact, after a long time, has resumed again the discussion of miners' rescue experts about whether it would be possible to implement the use of breathing apparatuses filtrating carbon monoxide into practice by the Mining Rescue Services of the Czech Republic in order to ensure a sufficient level of safety for mining rescuers even in an unexpected and rapid decline of the oxygen amount in the mine air at the site of the mine rescue service. The benefit of the breathing apparatuses filtrating carbon monoxide is their significantly lower weight, long protection period and also significantly smaller dimensions and design variability of the device. The disadvantages are higher breathing resistances and a higher temperature of the air mass inhaled from the breathing apparatus filtrating carbon monoxide.

Key words: Self-contained breathing apparatuses, carbon monoxide, mine rescue services.

1 INTRODUCTION

All interventions of the mining rescue services in an irrespirable environment are currently in the Czech Republic primarily and without any restrictions as to the type of intervention performed by mine rescuers equipped with working insulated overpressure regenerative devices with a closed circuit with a supply of medicinal oxygen. The above-mentioned breathing apparatus has a highly sophisticated design, reliability and high level of safety. In spite of this characteristic, mining rescuers for the last 15 to 20 years have been looking for ways, in which compressed-air breathing apparatuses could be used in practice of mining rescue services. Although these devices exhibit a shorter protective period than the insulated overpressure regenerative devices with closed-circuit using a supply of medicinal oxygen, they have, however, comparative advantages in apparatus design, its variable weight and also the temperature of the inhaled air mass. The breathing apparatuses filtrating carbon monoxide could become under certain conditions another suitable addition to the portfolio in the mining rescue services to the currently used working breathing apparatuses. These conditions must concern both the safety of users of the breathing apparatuses filtrating carbon monoxide and the comfort of their breathing.

2 WORKING INSULATED OVERPRESSURE REGENERATIVE DEVICES WITH CLOSED-CIRCUIT USING SUPPLY OF MEDICINAL OXYGEN

The only representative of the insulated overpressure regenerative devices with closed-circuit using a supply of medicinal oxygen used in the current practice of the Mining Rescue Services of the Czech Republic is a device manufactured by the company Dräger Safety AG & Co. KGaA, which is according to ČSN EN 145 [1] technically designated as a regenerative apparatus PSS BG 4 EPL EN 145/O2/4P.

The design of the regenerative apparatus PSS BG 4 EPL EN 145/O2/4P is shown in Figure 1 [4]. The used symbols: 1. breathing mask, 2. central connector, 3. exhalation hose, 4. CO_2 absorber, 5. breathing bag, 6. pressure relief valve, 7. pulmonary automatic system valve, 8. cooler, 9. fixed dose circuit, 10. inhalation hose, 11. discharge valve, 12. oxygen bottle, 13. pressure control valve, 14. BODYGUARD, 15. basic control unit monitoring unit BODYGUARD, 16. shut-off valve of the pressure oxygen cylinder

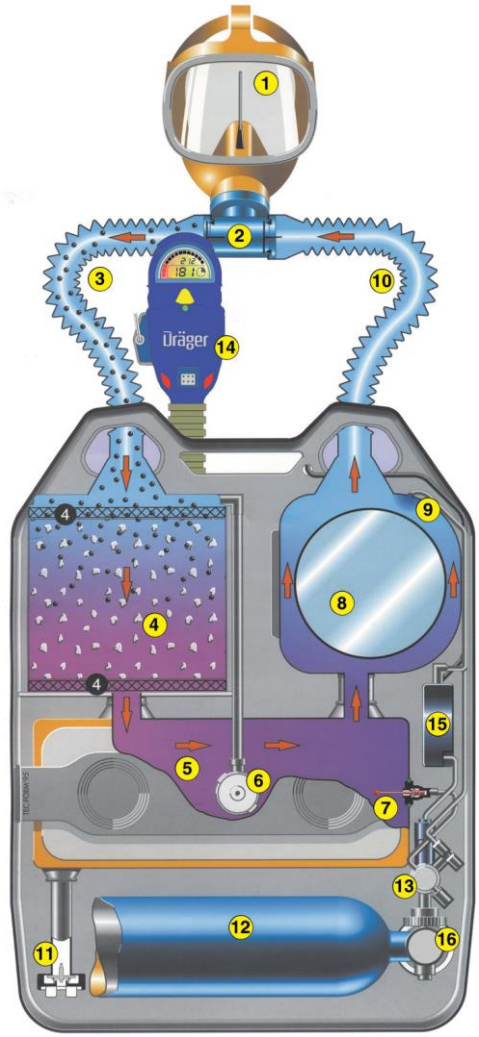

Fig. 1 Design of the regenerative apparatus PSS BG 4 EPL EN 145/O2/4P

Technical data of the regenerative apparatus PSS BG 4/E2/4P are summarised in the Instructions for use of BG 4 [4]. These instructions, following the provisions of § 6 let. c) of the Decree of the Czech Mining Office No. 447/2001 Coll., on Mining Rescue Services, and Item 2.5.2 of the Staff Regulations of the HBZS Ostrava, was issued by the Director of the Main Mining Rescue Station in Ostrava. The basic technical data of the regenerative apparatus PSS BG 4 EPL EN 145/O2/4P consist of the following operating conditions, characteristics, components and main parameters:

Operating conditions

Minimal temperature :		-6 °C
Maximal temperature (limiting the duration of use)	below 40 °C	4 hours
	below 60 °C	1 hour
	below 90 °C	15 minutes
Air pressure:		900 hPa to 1200 hPa
Air humidity		0 % to 100 %

Apparatus characteristics

Duration of use in moderate work		4 hours
Breath resistance		
(at breathing frequency f = 25 min^{-1}, breathing volume 2 l)	at aspiration	> 0 Pa
	at respiration	< 700 Pa
Oxygen doses measured at a pressure of 200 bar		
fixed dose		1,5 $l.min^{-1}$ to 1,9 $l.min^{-1}$
dose of valve of pulmonary automatic system		> 80 $l.min^{-1}$
dose of manual auxiliary valve		> 50 $l.min^{-1}$
Breathing bag volume		5,5 l

Apparatus components

Oxygen bottle PSS BG 4 EPL (hereinafter „bottle“) steel / 2 litres / 200 bar / G 3/4″	
filled with medicinal oxygen (hereinafter „oxygen“ or„O_2“) containing > 99.5 % O_2	
permissible contents of water vapours in non-compressed air	max. 50 $mg.m^{-3}$
Disposable CO_2 absorber or supercharging CO_2 absorber for repeated use	
filled with $Ca(OH)_2$ based absorbent mass, e.g. sorbent DRÄGERSORB®400	
Control and warning system **BODYGUARD** (hereinafter „bodyguard“)	
System intrinsic safety	EEx ia I
Power source – battery	6 LR 61 9 V
e.g.. Varta Alkaline®, Duracell Alkaline®, Daimon Alkaline®, etc.	
the permissible error of pressure measurement by a bodyguard at a pressure of 200 bar	± 4 bar
at a pressure of 40 bar	+ 0/-5 bar
Authorised mask for breathing apparatus BG 4	
Panorama Nova EPDM – PC – RP with a quick-coupler	

Apparatus main parameters

Apparatus mass	14.8 kg
with the cooler filling 1.2 kg of ice, mask and fully filled bottle	
Dimensions (height x width x thickness)	595 x 450 x 185 mm

The design and function of the regenerative apparatus PSS BG 4 EPL EN 145/O2/4P ensures such operation of the apparatus that provides to the intervening rescuer an air mass respiration for breathing for approximately 4 hours, thus ensuring the autonomy of his respiratory system in the surrounding atmosphere.

The breathing valves situated in the central connection block regulate the circulation of the breathing air mass in a closed respiratory circuit. This functional layout minimises the dead space and it significantly eliminates the onset of a possible breathing crisis in the case of incorrect breathing. Penetration of ambient air into the breathing circuit of the device is prevented by an overpressure in the circuit of the breathing apparatus with respect to the ambient atmosphere.

In the device circuit, the air mass is regenerated with use of oxygen from the cylinder:

- throughout the whole operation of the apparatus by a fixed dose valve,
- at higher volume capacity of breath by the pulmonary automatic system valve,
- in the case of a respiratory crisis with a manually controlled auxiliary valve.

Carbon dioxide contained in the exhaled air mass is primarily absorbed by the regenerative charge of the CO_2 absorber. From the charge of $Ca(OH)_2$ adsorbent, the excess moisture is secondarily precipitated in the breathing bag and the resulting condensate flows during manipulation with the apparatus into the discharge valve inlet. This valve continuously discharges the condensate from the breathing circuit of the instrument into the environment so that tightness of the given breathing circuit is not affected.

The regenerated air mass is cooled before inhalation by a cooler, which in itself ensures that the inspired air mass is cooled down to approx. 38.5 °C. In order to increase the efficiency of this cooler and to increase the respiration comfort of the user of the breathing apparatus, it is possible to insert an ice pack into the air mass intake cooler (the temperature of the inspired air mass with this ice charge is approx. 32 °C), but this is not a condition for perfect functioning of the breathing apparatus. The apparatus BG 4 is not designed for an underwater use.

3 WORKING COMPRESSED-AIR BREATHING APPARATUSES

Working compressed air breathing apparatuses were introduced into the practice of the mining rescue services of the Czech Republic at the end of 2010. This was specifically the working compressed air breathing apparatus PSS 7000 manufactured by the company Dräger Safety AG & Co. KGaA. This device has a shorter protection period (90 minutes) compared to the protection period (240 minutes) of the regenerative apparatus

PSS BG 4 EPL EN 145/O2/4P. Compressed air breathing apparatuses have, however, a very popular outlet of breathing hoses led under shoulders, which allows for the greater comfort of work in the breathing apparatus. Its principal comparative advantage is the temperature of the inhaled air mass, which varies from 18.5 °C at the 30th minute of its use to 16 °C at the 60th minute of use. The disadvantage of the primarily higher weight (18 kg) of the compressed air breathing apparatus PSS 7000 is compensated for by a gradual decrease of this weight during the use of the instrument, when due to the consumption of compressed air, the primary mass of the instrument drops to the final weight of the "empty" device of 13.1 kg.

The design of the compressed air breathing apparatus PSS 7000 without pressure cylinders, as well as with the pressure cylinders is shown in Figure 2 [5].

Fig. 2 Design of the compressed air breathing apparatus PSS 7000

4 WORKING SELF-CONTAINED BREATHING APPARATUSES FILTRATING CARBON MONOXIDE

Self-contained breathing apparatuses filtrating carbon monoxide is generally exploitable for such types of the mining rescue services where the irrespirable mining atmosphere contains high harmful concentrations of carbon monoxide, but at the same time, this atmosphere contains enough oxygen for the breathing physiology of mine rescuer.

In practice of the mine rescue services of the Czech Republic the working self-contained breathing apparatuses filtrating carbon monoxide is not used yet. However, the German Mining Rescue Services considers using this type of working breathing apparatus under the following conditions [3]:

- breathing apparatuses are assembled and tested before use,
- working self-contained breathing apparatuses filtrating carbon monoxide are used with mouthpieces or full-face masks,
- sergeant checks with the use of hand-held measuring device the oxygen content in the winds (at least 18%), the carbon monoxide content (max. 500 ppm) and the dry ambient temperature at the site of the rescue intervention (<32 °C),
- oxygen content and the carbon monoxide concentration are measured continuously by the hand-held measuring device,
- climate values at the site of the rescue intervention are measured once per shift,
- speed of the mine winds at the site of the rescue intervention is at least 0.5 msec^{-1},
- deployment time is generally 2 hours, followed by a break of at least 1 hour,
- duration of use may be possibly shortened in respect to the climatic values at the site of the rescue intervention according to the rescue intervention tables,
- when shortening the time of deployment based on climatic conditions (rescue intervention tables), a two-hour break must be maintained,
- mine rescuer can be deployed max. twice a day,
- in special cases, the two-hour period of use may be exceeded subject to the approval of the rescue manager,
- mine rescue worker must be trained how to handle the appliance and he must know what are the special conditions of its use.

A possible two-container arrangement of carbon monoxide filters on the back carrier is shown in Figure 3 [3]. This arrangement is chosen in order to reduce the breathing resistance of a working self-contained breathing apparatuses filtrating carbon monoxide.

Fig. 3 **Two-container arrangement of carbon monoxide filters on the back carrier**

Containers with carbon monoxide filters shown in Figure 3 are currently manufactured e.g. by the Polish company "FABRYKA SPRZĘTU RATUNKOWEGO I LAMP GÓRNICZYCH „FASER" S.A." or German company MSA Deutschland GmbH.

The container with carbon monoxide filters has the following technical parameters [2]:

Dimensions (height x width x thickness)	265 x 140 x 70 mm
Thread of hose connections	Rd 40 x 1/7" according to ČSN EN 148-1
Filter mass	180 g
Breathing resistance	in accordance with point 7.11 ČSN EN 141:2000
during flow of 30 $l.min^{-1}$	< 2.6 mbar
during flow of 95 $l.min^{-1}$	< 9.8 mbar
Minimum time of breathing protection time at carbon monoxide concentration of 0.25 % and at air humidity content of 20.7 $g.m^{-3}$, which corresponds to the relative humidity of the mine atmosphere rh of 85 to 90 % at a sinusoidal flow rate of 30 $l.min^{-1}$	at least 210 minutes
Shelf life	4 years and 6 months from the date of manufacture

The Main Mine Rescue Station in Ostrava has been continuously in the long term dealing with the possibility of the use of working self-contained breathing apparatuses filtrating carbon monoxide. The use of these working breathing apparatuses is possible in conditions of an irrespirable mine atmosphere containing high concentrations of carbon monoxide, but also containing sufficient oxygen for the mining rescuer breathing physiology. The safety conditions for such use can be fully taken over from the practice of the German mine rescue services.

However, due to the massive preventive and repressive inertisation of the mines of the company a.s. threatened or affected by mine fires, there exists a permanent threat of a sudden and sharp drop in oxygen content in the mine atmosphere occurring at the site of the rescue intervention of mine rescuers. For this reason, a design solution for working self-contained breathing apparatuses filtrating carbon monoxide is currently being developed, which consists of adding of the cylinder with medicinal oxygen and the so-called "HELP BUTTON" into the structure of the device. This solution will make it possible in the case of the critical drop of oxygen in the mine atmosphere at the site of the rescue intervention of mine rescuer to immediately supplement the necessary amount of oxygen into the air mass inhaled by the rescuer in order to allow him to go to the places with sufficient oxygen concentration and possibly to change and start using another type of working or self-rescuer.

A possibility of cooling the carbon monoxide filter containers by means of a gel cooler is also considered in order to increase the breathing comfort of a mine rescuer using a working self-contained breathing apparatus filtrating carbon monoxide.

5 CONCLUSIONS

The use of a working self-contained breathing apparatus filtrating carbon monoxide in practice of the mine rescue services offers indisputable advantages, especially thanks to small dimensions of the breathing apparatus and its low weight. The disadvantage of this breathing apparatus consists in certain safety risks at its use, especially the risks resulting from the critical drop of oxygen in the mine atmosphere occurring at the site of the intervention of mine rescuers. Another disadvantage of the use of a working self-contained breathing apparatus filtrating carbon monoxide at the mining rescue services is certain breathing discomfort caused by the temperature of inhaled air mass or by the increased respiratory resistance resulting from carbon monoxide filtration of the inhaled mine atmosphere.

By completing the technical intention of adding a cylinder with medical oxygen and the so-called "HELP BUTTON" into the structure of the device, as well by solving the gel cooling of the carbon monoxide filter containers located in the device, it is possible to expect that the working self-contained breathing apparatus filtrating carbon monoxide will become a fully-fledged protection of the respiratory organs of mine rescuers making interventions in environments with an increased carbon monoxide content and sufficient oxygen content.

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